

Monthly Progress Report #31
for the
CHANDRA HIGH RESOLUTION CAMERA (HRC)

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HRC Monthly Progress Report #31

Sept 2004

1 Management and General Status

The HRC expenditures are at or below the budget estimates for this month. The Mission Support and Operations and Science Activities are detailed below.

2 Mission Support and Operations

During this reporting period, the HRC mission operations team has supported the following the routine support activities:

- Real Time monitoring of the operational state of the HRC instrument during each real time pass.
- Processing and reviewing the HRC portion of the weekly command loads.
- Acquisition, archiving, and generation of HRC science and engineering products from flight telemetry.
- Investigating long term trends and analysis of HRC science and engineering products.

In addition to the routine support activities listed above, the operations and engineering team has supported the following tasks:

- POC modifications:
We have completed work on modifying the HRC POC electronics system in anticipation of integrating the ASVT with the HRC POC. We are now working with the FOT/ASVT team on integrating the HRC POC into the ASVT.
- Failure Analysis of HRC Flight Relay We have completed the Failure Analysis of HRC Flight Relay. This has been incorporated into a flight note being prepared by Mike Juda. (See Attached)

3 Science Activities

The HRC science team has continued to support the Chandra operations during this reporting period.

Organization:

Smithsonian Astrophysical Observatory

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Program/Project:

Chandra High Resolution Camera

Title:

Technical Memorandum Failure Analysis of HRC Flight Relay

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Contents

1 Introduction	1
2 Background	1
3 Preliminary Failure Analysis	1
3.1 Residual Gas Analysis (RGA)	1
3.2 Decapping	2
3.3 High Humidity (50% RH) and Temperature Extremes (75C, 40C)	2
3.4 Oxidizing Environment	2
4 Preliminary Conclusions	2
4.1 Failure Analysis	2
4.1.1 Residual Gas Analysis (RGA)	2
4.1.2 Moisture Content and Relay Operation	3
4.1.3 Particle Contamination	3
4.1.4 Oxidation	4
5 Conclusions	4
6 Recommendations	4
7 References	5

List of Figures

List of Tables

1 Residual Gas Analysis results	1
2 Relay Identification	3
3 RGA Analysis	3

1 Introduction

Following the determination that the -Y shutter motor select relay failed, a failure analysis was initiated to determine the cause of the failure. The intent was to provide a basis for deciding if it was possible to recover the proper operation of the relay, as well the impact of the failure on the continued use of the other motor select relays.

2 Background

The Genicom relays (S311P754/09-003; DC9536) used for the Flight HRC motor selection were qualified to GSFC specification S311P754 including PIND test per MIL-R-83536 for detection of fine particles. These relays have an excellent reliability history in space programs with no failures. A review of the documentation received with Chandra relays showed that the lot for Chandra was selected from a lot of 24 relays that had two failures during processing (1-vibration, 1-seal).

The relays have gold plating over nickel underplate on contacts; such contact coating has no history of flaking and causing particles. Particle contamination is one of the major causes for relay failure.

The Proof of Concept (POC) HRC electronics utilize the same relays except for additional screening imposed by GSFC S311754 requirements. The POC system has been in operation since 1994.

3 Preliminary Failure Analysis

Unfortunately there was only one flight relay in spare stock. So preliminary analysis was conducted on POC relays and MIL GRADE relays from Genicom and Tyco.

3.1 Residual Gas Analysis (RGA)

An RGA was performed on a POC relay (3SBH1347A2, Genicom) to determine contamination levels in the relay package. The data is presented below (1).

Element	%
Nitrogen (N)	99+
Carbon Dioxide (CO_2)	0.113
Moisture (H_2O)	0.177

Table 1: Residual Gas Analysis results

3.2 Decapping

The relay was decapped by grinding, taking care not to introduce particles within. The decapped relay failed a switching test in a similar mode as observed in the flight HRC. The failure was found to have been caused by distortion of the assembly during decapping. After repair the relay was found to operate normally.

A particle contamination was simulated by inserting a .002" thick piece of paper in the contact mechanism. It produced the failure mode observed in orbit. Particle contamination was thus established as one of the possible failure modes in orbit.

3.3 High Humidity (50% RH) and Temperature Extremes (75C, 40C)

POC and Genicom MIL GRADE relay were subjected to extremes of temperature (75C, 40C) and high humidity (50% RH) for varying periods of time. No failures were observed.

3.4 Oxidizing Environment

The RGA suggested the possibility of an oxidizing environment within the relay package, consisting of H, N, and O (constituents found in nitric acid fumes). A decapped POC relay was subjected to 5% nitric acid fumes at 25C for 12 hours, resulting in a failure similar to that observed in orbit. Six consecutive switching attempts were required to correct the relay operation. (Extended exposure to fumes (300 hours) caused heavy oxidation of copper elements a worst-case scenario). Thus oxidation in gaseous environment within the relay package was established as a source of particles and a possible failure mechanism.

4 Preliminary Conclusions

The analysis suggested the following factors as probable cause for the HRC failure in orbit:

1. Particle contamination
2. Oxidizing environment in the relay package as the primary source for particles.

4.1 Failure Analysis

On the basis of the findings of preliminary analysis, failure analysis was conducted on following relays:

4.1.1 Residual Gas Analysis (RGA)

The results of the RGA are shown in Table 3.

Relay	Part No./Date Code	Manufacturer	Status
1	S311P754/09-003/9536	Genicom	Flight
2	3 SB145134K / 9452	Genicom	MIL GRADE
3	3SBH1665A2 / 2002	Genicom	MIL GRADE
4	3 SB145134K1 / 2003	Tyco	MIL GRADE

Table 2: Relay Identification

Elements	Relay 1	Relay 2	Relay 3	Relay 4
Nitrogen (N)	98	99	86	98
Argon (Ar)	.032	.032	.185	.029
Carbon Dioxide (CO ₂)	.058	.063	.63	.083
Moisture (H ₂ O)	.92	.258	12.10	.75
Hydrogen (H)	.32	.174	.161	.167

Table 3: RGA Analysis

The data confirmed the previous finding of an oxidizing environment. In addition, it showed significant moisture content within the flight relay.

4.1.2 Moisture Content and Relay Operation

To study the effect content (up to 12.1%), a measured amount of moisture (0.87 cc), determined from the RGA data and dimensions of the relay package was introduced in decapped relays (#1, 3 and 4). These relays were selected because of their high moisture content. The relays were tested at 25C and were found operational.

The relays were then stored at 45C in quiescent state for 22 hours. At the end of 22 hours, the relays operated normally at 45C. Relays were then stored at 60C in quiescent state for 2 hours. Tests at 60C, 40C and 10C showed normal operation.

It was therefore concluded that moisture content up to 12% had no effect on relay operation under normal humidity condition.

4.1.3 Particle Contamination

Siltek, a diamond powder with particle size of 0.5 (m was used for contamination of two relays (#3 and 5). Three particles were deposited on top of the decapped relays, and the relays were then tapped lightly to allow random, free fall of the particles into the contact assemblies. Both relays failed in a similar mode as observed in orbit. Relay #3 was then stored in quiescent state at 40C for 150 hours in an oven that tended to vibrate whenever the blower fan was energized. At the end of 150 hours, the relay exhibited the same failure mode. So particle contamination as a source of relay failure was

established.

4.1.4 Oxidation

The objective of the oxidation tests was to simulate the long-term storage condition experienced by the failed YSMS relay in Chandra, and to prove oxidation as the primary source for particles within the relay package.

Two relays, #2 and 4, were exposed to nitric acid (5%) fumes after initial switching tests in a quiescent condition for 24 hours. The switching test at 24 hours showed normal operation, with the appearance of thin oxide layers. The relays were then subjected to nitric acid fumes for 150 hours. At the end of the 150 hours relays were found to be heavily oxidized worst case situation in long-term quiescent storage. The oxide layers are shown in the attached photographs.

This strongly suggested the growth of oxides on copper elements of the contact assembly over a long period of exposure to oxidizing environment and the oxidation as the primary source of particles in the relay.

5 Conclusions

The RGA of the Chandra flight relay showed significant moisture content (0.92%) in the relay package. Such an environment at room temperature is considered ideal for oxidation of copper and copper alloys.¹

The possibility of particles from external sources (such as gas supply, processing) was discounted because the relays were processed and tested per GSFC S311574 specification including PIND test. Additionally, the documentation received with the relays showed no anomalies.

The failure analysis concluded that the relay failure in orbit was likely caused by particles; the particles being generated as a result of oxidation of the copper elements of the contact assembly during long term storage (4 years) in oxidizing environment. This failure mechanism suggests that all the HRC motor select relays on- orbit have the potential to fail in a similar fashion.

6 Recommendations

The HRC door mechanism should not be exercised. The door requires the its motor select relay to operate properly to both close and open the door. The door does not have any failsafe features in the mechanism in the event that the door was closed and the motor select relay failed at that time. This would leave the HRC door permanently closed and render the HRC useless for the remainder of the mission.

The HRC shutters do have a failsafe mechanism to remove the shutter blades from the field of view in the event that a motor relay fails. (Note that the failsafe mechanism is a one-shot, non-resettable mechanism). At the current time, the -Y shutter relay has failed and is presumed to still be failed.

Periodic attempts to select the -Y shutter motor could be done without actually deploying the shutter to see if the relay can be recovered. There is no known problem with the +Y shutter. The only drawback to the use of the shutters and reliance on the failsafe features to overcome a relay failure is the use of Starsys wax actuators in the failsafe mechanisms. Actuator of a similar type experienced failures due to burn-out of the heater prior to full actuation. Such a failure would result in the shutter blade still in the field of view, again rendering the HRC useless. This problem with the wax actuators was known prior to launch, but a decision was made not to replace them, but to overcome any potential problem operationally. The plan was to develop a procedure whereby the actuator would be turned on for brief intervals to allow the wax to heat up slowly without having to leave the heater on continuously. Heater elements of the type used in the HRC actuators were obtained from the manufacturer of the actuators for use in laboratory testing to determine the proper heater duty cycle. These tests were never conducted and no procedure was ever tested on the flight instrument. There is, therefore, some risk that the failsafe function of the shutter mechanisms could fail to function properly in the event of a shutter motor relay failure.

The HRC calibration mechanism is of no interest as the strength of the Fe55 source has diminished to the point that it is no longer useful.

7 References

1. Handbook of Materials and Techniques for Vacuum Devices, Walter H. Kohl, Rheinhold Publishing.